Identification of an Odour Source from Various Probable Sources in an Industrial Wastewater Treatment Plant

M. Habip, A. Tripathi, Transoft International, Saint-Denis, France

Abstract

Numerical simulation of pollutant dispersion from a given source is commonly possible based on various known models, such as, among others, Gaussian, Lagrange, Puff, and Euler.

Quite frequently, however, the reverse problem of source identification must be solved whenever inhabitants complain about a disturbing odour from a neighbouring facility as, for example, in the case of the SIAAP wastewater treatment plant at Valenton, near Paris, the largest of its kind in Europe.

In the past, the method of puff releases from all probable sources in this large facility was used in order to follow their path to the particular locations of the complainers where the odour was detected.

The current paper will review new possibilities of performing such odour source retro-tracking analyses in the future in order to optimise plant operations under variable environmental constraints.

1. Introduction

To answer the increasing demand on controlling the emission of industrial odours, several strategies of quantification have been developed. A number of them are related to the experimental diagnosis, through a network of surveillance (electronic or human noses). These methods, however, are costly and difficult to implement. The outcome is also purely qualitative without providing any means of improvement (Boolean Yes/no detection rather than quantitative estimate).

Another strategy of quantification is also provided by the use of modelling the odour plume from the source to the sensitive areas. In order to provide the most precise results, the 3D modelling of the atmospheric flows, turbulence fields and transport of the gas mixture or compounds is recommended. Among the numerous advantages of such techniques, one can list : a precise description of the plumes, the possibility to work without advance knowledge of the emission level and the possibility to locate and quantify the emission source in real-time for an optimal management of the industrial units and the prevention of any complaints.

The emissions at the origin of odours are often diffuse emissions, not submitted to any treatment or any capturing. They are prone to variations due to the process (biological or chemical) and meteorological conditions such as the wind speed, the ambient temperature, or solar radiation and mixing. The transport of the pollutant plays a major role in the perception. The diffuse sources are often emitting near the ground and their dispersion is very sensitive to the surface flows. Therefore obstacles such as undulations and buildings have a strong impact.

All these methods are based upon the 3D simulation of flow : equations for the three components of velocities, pressure, temperature and turbulence. According to the scale, the simulations can be done :

- In a direct way (emission source to captors) to identify an average long term impact (annual for example) based on the wind rose of the site with Euler solutions.

- In a direct way (emission source to captors) to identify an short term, unsteady impact. For these cases, the Lagrangian methods are preferred in real-time simulations.

- In a indirect way from a number of monitored points (x,t), in retrotracking to identify the source of emission. For a given detection on one or several monitor points, the simulation allows to find the probability weights for each source of emission found on the inverse trajectories.

Fig. 1: Aerial photograph of the Valenton site (courtesy of SIAAP)

One industrial case, illustrating the methodology stated above has been chosen for illustrating the method above. The SIAAP (Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne) is the wastewater treatment company for Paris and its suburbs. It treats 3 millions m^3 of wastewater per day coming both from individual homes and industrial sites. The SIAAP is made of 4 units : Seine Amont, Seine Aval, Seine Centre and Marne Aval. The site of Seine Aval described in this study is located in the town of Valenton, west of Paris. It deals with carbonated and nitrogen pollution.

For this particular case, the French company TRANSOFT International has used its extensive expertise in the domain of 3D environmental modelling as well as Computational Fluid Dynamics in the form of a software called *fluidyn*-SIAAP. *fluidyn*-SIAAP software is a dedicated software tailored to the SIAAP needs and based on *fluidyn*-PANEIA; a software for industrial pollutant dispersion in the atmosphere and developed by TRANSOFT International. The *fluidyn*-SIAAP software differs from *fluidyn*-PANEIA by two very innovative modules :

- Real-time dispersion
- Source identification

Based on the numerical model of terrain of Valenton, four questions have been investigated using the dedicated software *fluidyn*-SIAAP :

1. Optimisation of the monitoring point location
2. Impact study of the odours
3. Identification of odours by retrotracing
4. Real-time dispersion of odours

2. Numerical model of terrain for Valenton

The Valenton site is located near the river Seine and is made of 23 tanks of water treatment. The pollutant H_2S has been used as representative of the odour amount for global emission in odour units/m^3. This standard is related to the way the French authorities are evaluating the odour levels regardless of its composition.

Based on the Survey map of the region, the terrain is drawn as shown in fig. 2. The brown areas are urban areas, the green areas are forests and fields. The red curves are the altitude curves from which the software will take the information about the third dimension. The blue areas are water bodies.

These areas are characterised by a specific roughness coefficient as well as a particular temperature or heat flux.
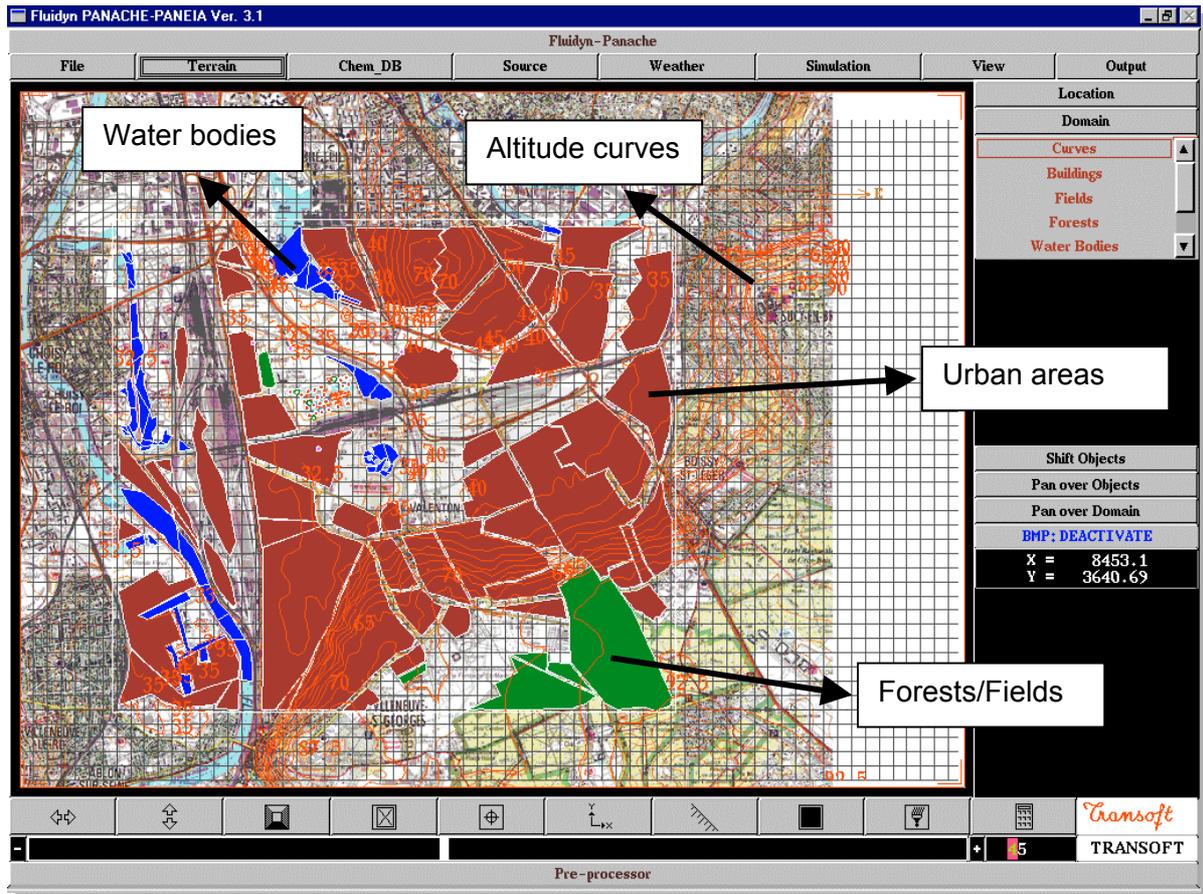
Fig. 2: Numerical model of terrain as created in the fluidyn-SIAAP software
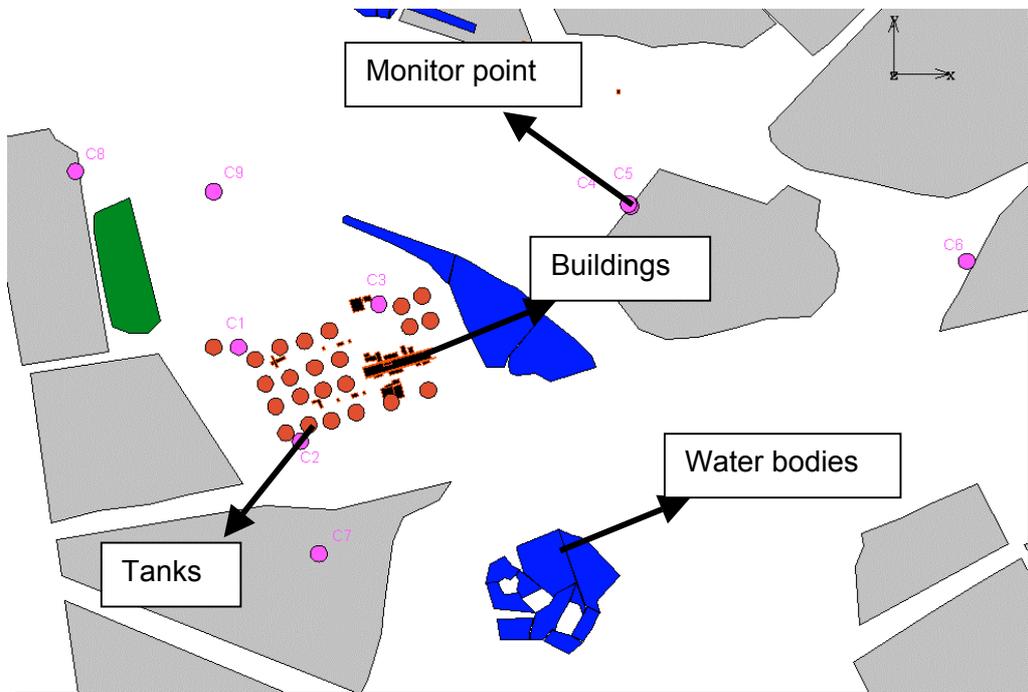

Fig. 3: Zoom on the water treatment plant

The site is modelled using volumetric entities for the buildings. It is of primary importance that the buildings should be fully described as their impact on windfields close to the source will condition the odour trajectory. In Fig 3, a zoom is made on the site. The grey areas are urban areas, the buildings are shown in black outlined with red, the tanks and sources of emission are in red and the monitoring points are in pink.

The mesh (Fig 4) is created in 3D automatically by the software. It is curvilinear, structured and non-uniform as it is refined near the buildings and sources.
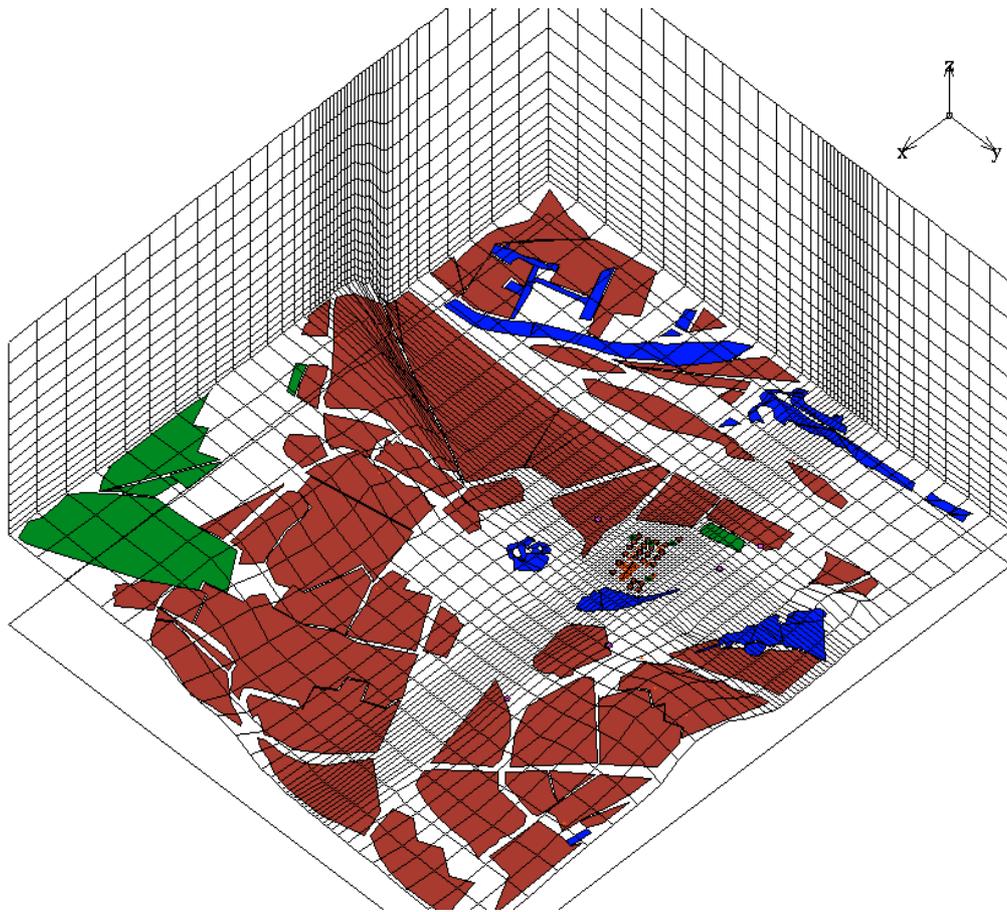
Fig. 4: Three-dimensional mesh following undulations of the terrain

3. Location of monitoring points

The first step of the simulation is to converge the dynamic fields (wind/turbulence/temperature) taking into consideration the buildings the undulations of the terrain and the various roughness coefficients.

As an example, the Fig 5 shows the wind vectors at a height of 1.5 m above the ground in a complex structure. The recirculation zones and accelerations due to the buildings are clearly seen. From this simulation, another very important result can be found which concerns the

turbulence fields. From this, the optimal location of monitoring points can be inferred. By choosing locations where the turbulence is low and where there are no stagnation or recirculation areas, one insures that the measurements will be as steady and reliable as possible.
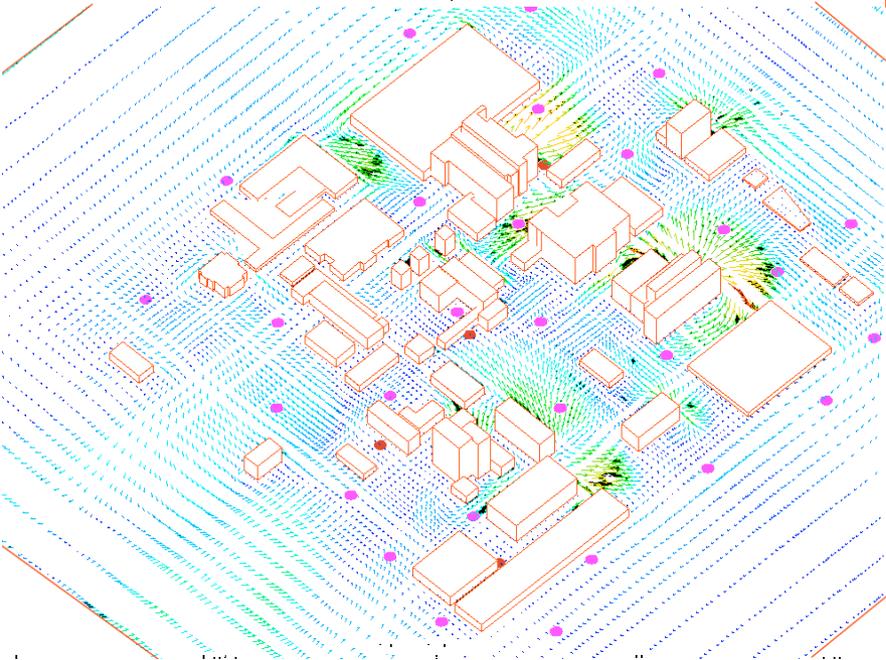
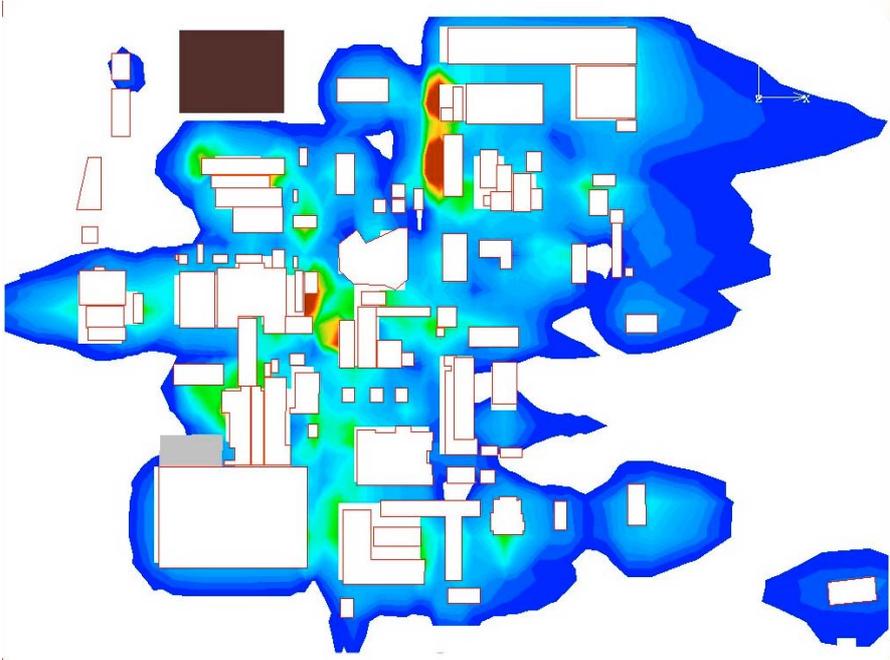Fig. 5: Wind vectors on the first horizontal plane (height = 1.5 m)

Fig. 6: Turbulence on the first horizontal plane (height = 1.5 m)

4. Average impact of odour

After the wind fields have been modelled for each wind condition (direction and speed), the numerical sources are emitting and dispersion is computed using the transport equations. As for the measurements, the numerical simulation outputs can be expressed in terms of concentration for some species (H_2S for example) or for a virtual air parcel loaded with odorous molecules unidentified expressed in odour-units/m^3.

Such simulations provide transfer functions between various sources and reception areas in offering variability analysis induced by meteorological variation

Fig 7 gives an example of the dispersion of H_2S along a particular wind direction.

Once all dispersions have been done, they can be averaged according to the annual wind rose to get the annual impact of the source.
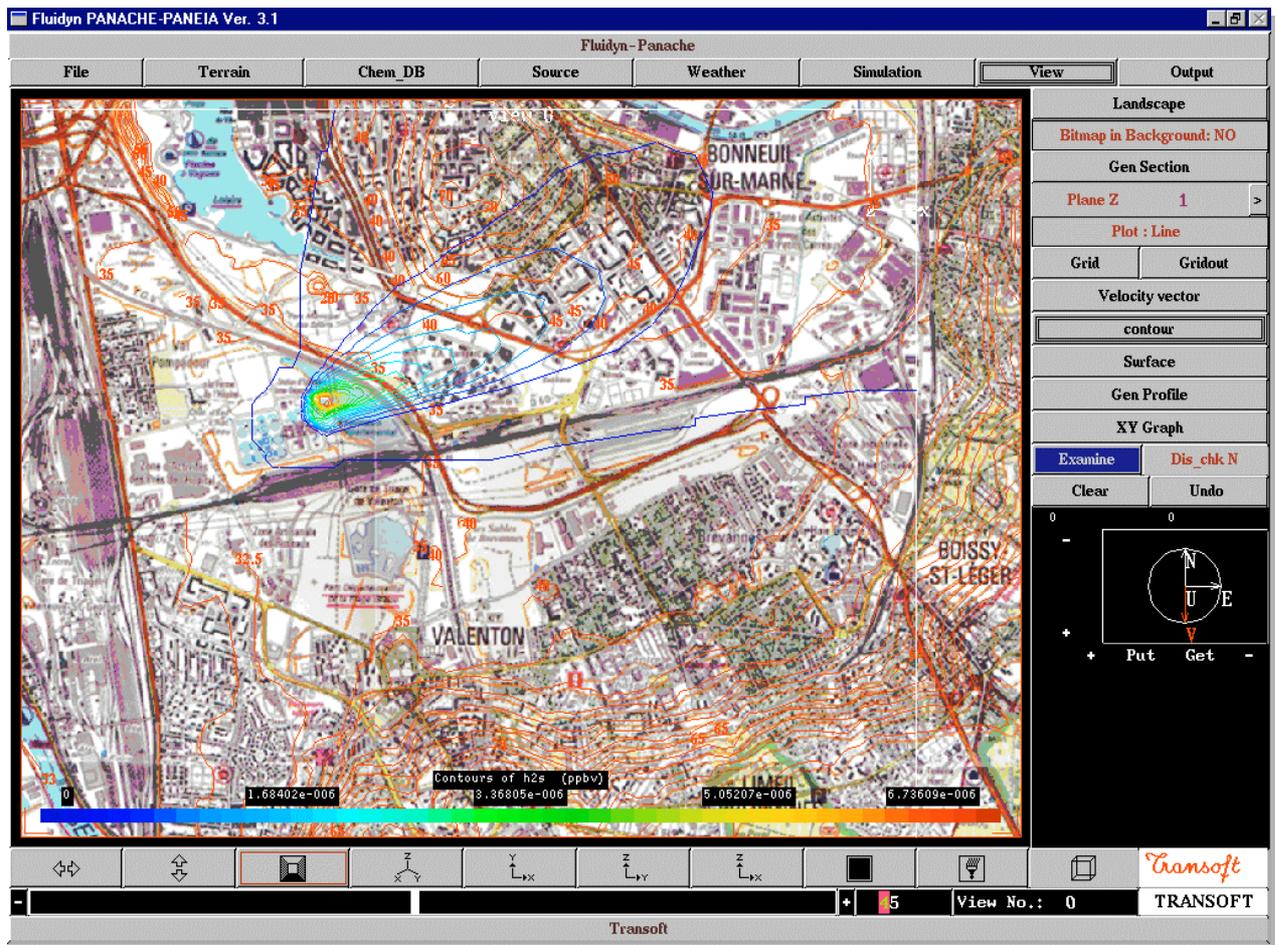
Fig. 7: Contours of concentration of H_2S at a height of 1.5 m

5. Real-time odour dispersion

Once the terrain has been set up and the wind fields have all been determined and stored (steps 0-a and 0-b of the schematics in Fig 9), the software is set to receive information every 30 minutes from weather stations distributed on the site (step 1). The information comprises : wind direction, wind velocity, temperature, humidity and vertical profiles if available.

From this information and from the wind field already stored, the software updates the simulation in real-time and sends Lagrangian puffs from the sources. The Lagrangian puff model has the distinct advantage of being very fast, especially for nowadays computer power. The wind interpolation between half-hours is done by the optimal variational interpolation based on mass and vorticity.

An example for the dispersion of H_2S at a specific time is shown in Fig 8.

6. Retro-tracking for source identification

The module for retro-tracking fits in naturally. In this case, a monitor point set at the boundary of the site upwind to the sensitive areas will be triggered by a predetermined concentration and will send a signal off to the software (step 2 of the diagram of Fig. 9). The software will then backtrack in time for a few minutes (as early as needed for the tracking trajectory to reach back the emission areas) and start emitting puffs from all the sources to the location of the captor to compute the probability for each source to be responsible for the alarm (step 3). Of course the emission estimations can be refined to the correct values by confronting the concentrations measured at some monitor points with the computed transfer function (step 4). The results of the simulation (step 5) can therefore be :

- The assessment of the detection validity
- The action on likely emitting sources
- The correction in the model for new odor map

7. Conclusion

TRANSOFT International has developed a numerical platform for the waste water treatment company for the Paris region (SIAAP) based on *fluidyn*-PANEIA, a robust software for dispersion of pollutants in atmosphere. This software is already implemented on SIAAP industrial site and provides results for the average impact. The methodology developed here will be implemented for the real-time management of the process in order to take actions before the complaints from the neighbourhood. This methodology could also be effective for emergency planning and response in case of industrial accidents.
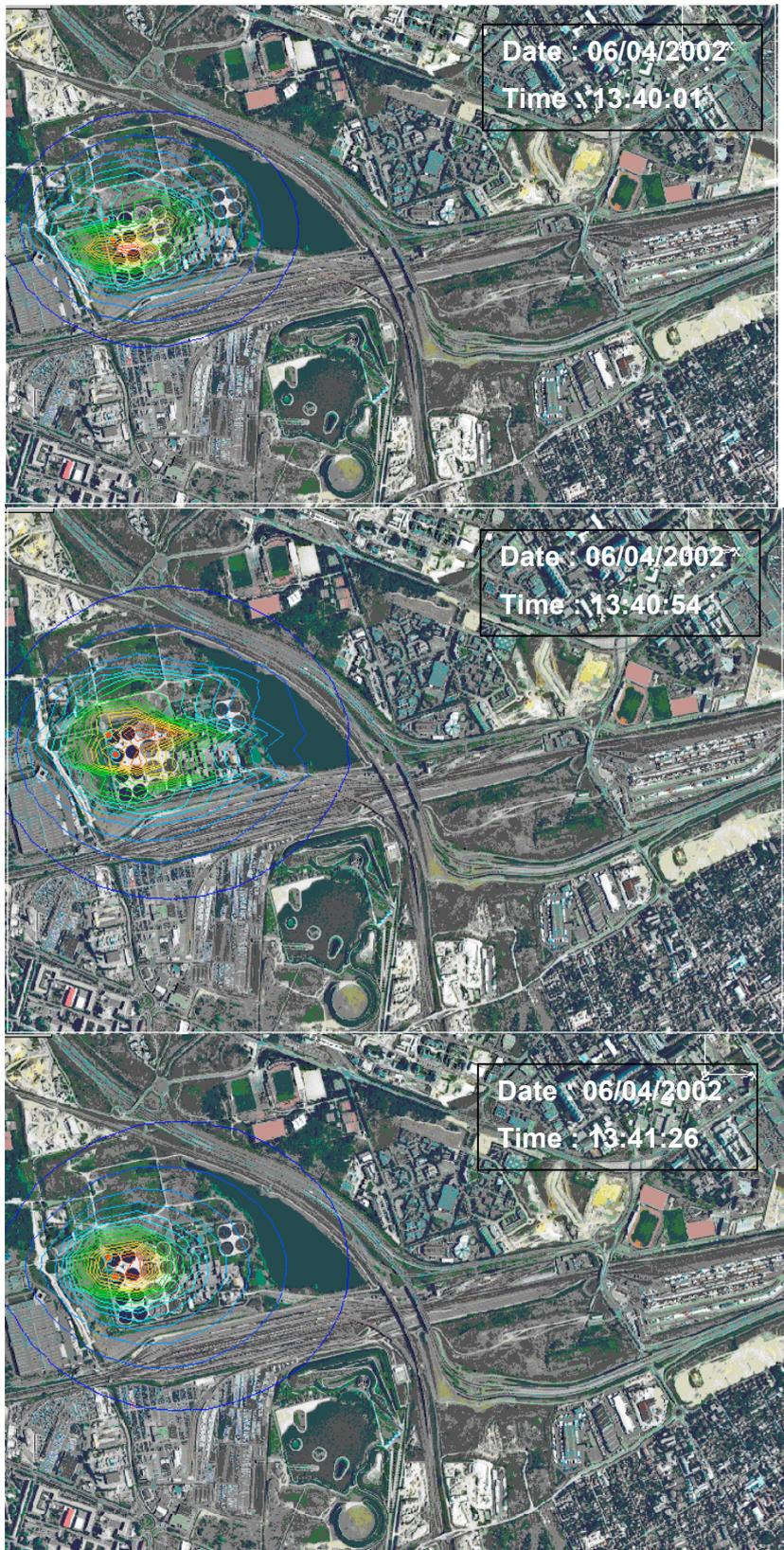
Fig. 8: Contours of concentration of H$_2$S (ppmv) according to monitored meteorological data evolving in time

Meteo station

Monitoring

Every 30 minutes

1

Alert

2

Terrain

Simulations
Loop with
monitored data

0-a

3

Actualisation
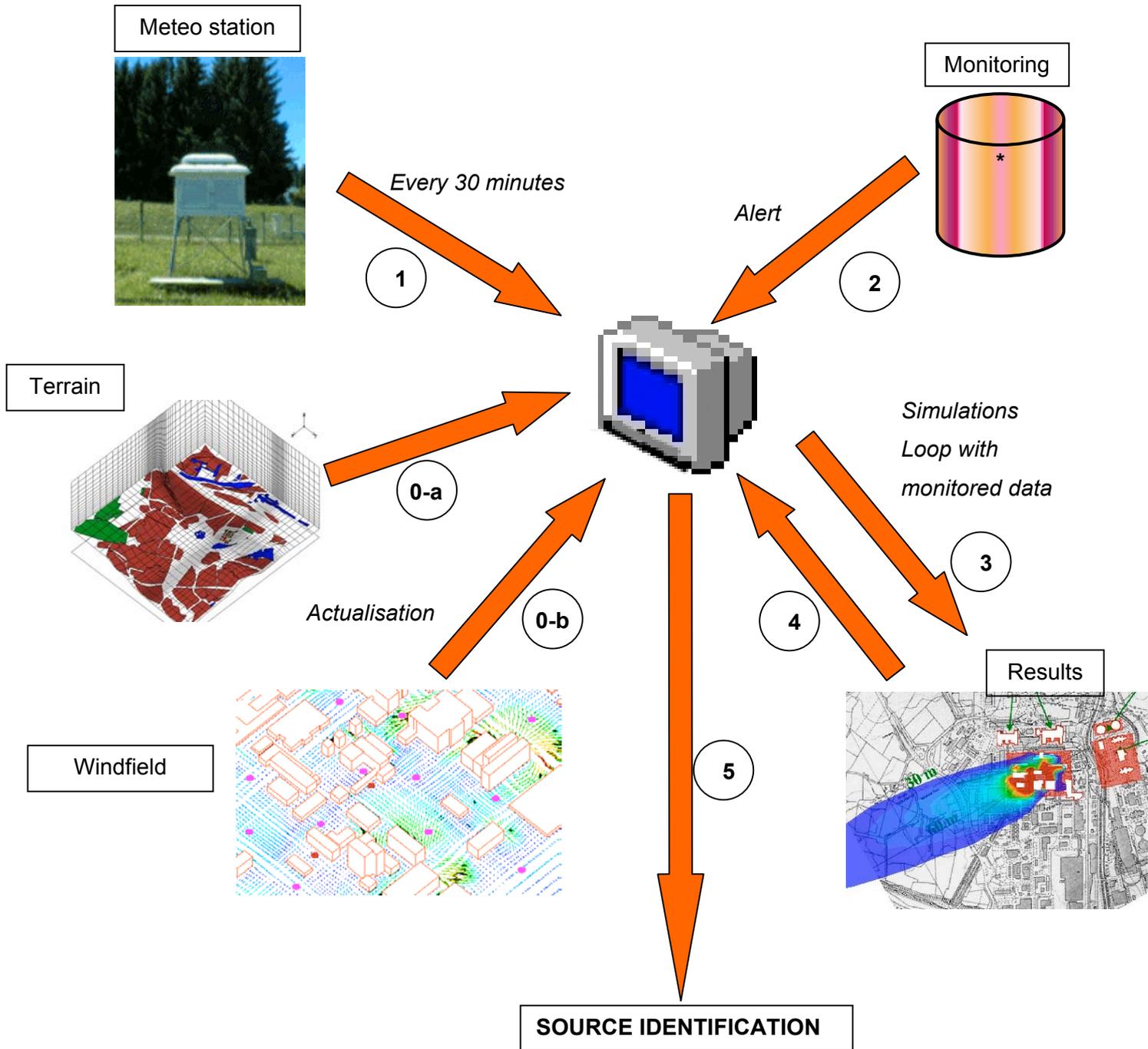
0-b

4

Results

Windfield

5

SOURCE IDENTIFICATION

Fig. 9: Methodology for source identification in real time

Identification of an odour source from various probable sources in an industrial waste water treatment plant

M. Habip and A. Tripathi

FLUIDYN France

FLUIDYN-France / TRANSOFT International

- French company created in 1987
- Two poles in simulation :
  - Industrial processes : CFD, Fluid structure interactions, Heat transfer
  - Environment / industrial risks : Gas dispersion, explosions, fires …
- Three main activities :
  - Provider of general software (*fluidyn* series)
  - Development of customized software dedicated to specific applications
  - Consultancy studies
- Several subsidiairies in the world : Asia, US, UK, Germany

S.I.A.A.P.

- Waste water treatment company for Paris and its region
- 3 millions of m3 of waste water per day from homes and industries
- 4 water treatment units : Seine Amont, Seine Aval, Marne Amont and Marne Aval located in urban areas
- H2S coming from 23 possible sources

Problems

- Reduce the number of sensors on site to efficient ones
- Fast treatment of source after alert on sensor (before complaints)
- Odour dispersion quantification for better communication

The *fluidyn*-SIAAP software

- Software based on fluidyn-PANEIA
- Dedicated for the following applications :
  - Determination of optimal location of sensors / monitors
  - Source identification after alert
  - Dispersion in average and real-time results
- Easy and fast operation by maintenance workers

3D modelling of dispersion : fluidyn-PANEIA

- Resolution of fluid dynamics equations (3D Navier Stokes)
- Chronic dispersion of gas, aerosols, particles.
- Resolution of turbulence fields (k-e model)
- 3D curvilinear mesh
- Transient simulations for wind and dispersion
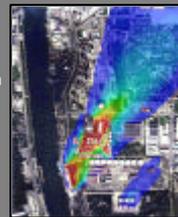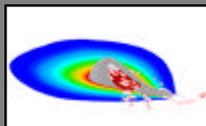
Features

- Coupling with maps, GIS, aerial photos
- Taking into account :
  - Ground occupation : topography, obstacles
  - Turbulence
  - Weak winds
  - Variable weather conditions
  - Near-field results

Customized interface

I. Optimisation of source location

Methodology of simulation

- Terrain
  - Set-up from aerial photographs and stored
- Windfield
  - All wind conditions prepared in advance
  - Weather stations on site linked to the software
- Emission
  - Emission computed by software
  - Link with on-site observation
- Dispersion : Gaussian / Puff model / Eulerian

Numerical model of terrain

Numerical model of terrain

Monitor points
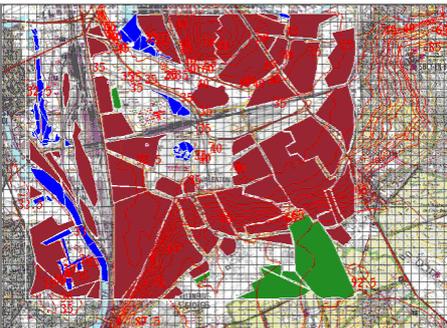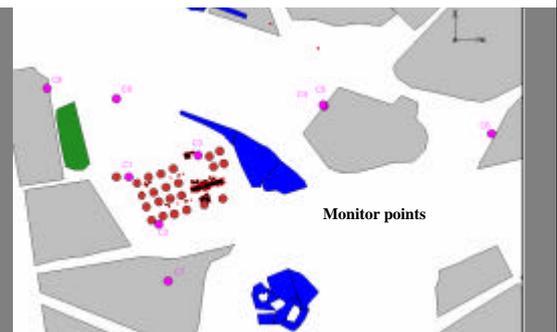
Numerical model of the site
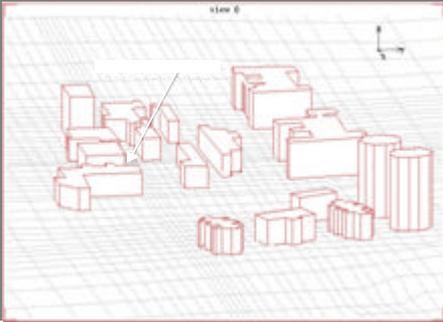
Weather station definition
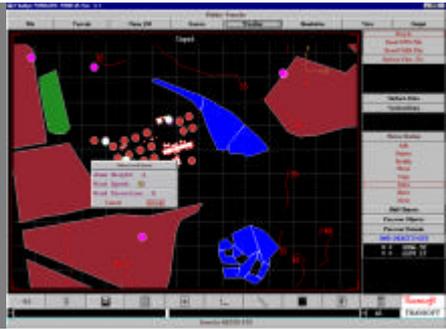
3D mesh
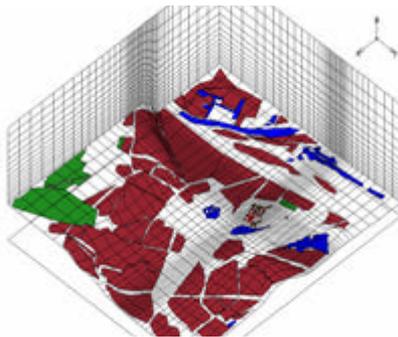
Windfield simulation
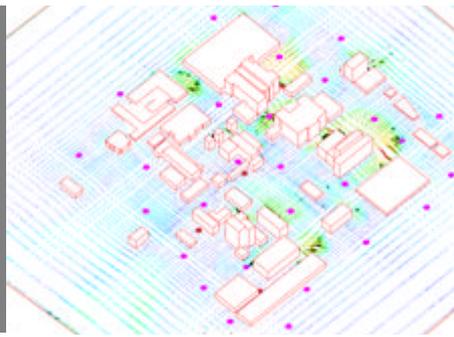
Windfield simulation
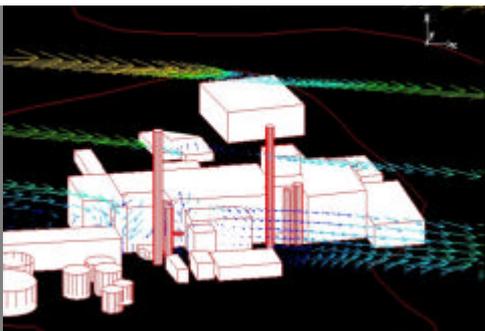
Turbulence fields
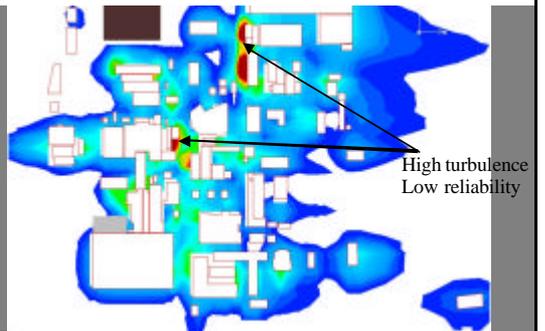
High turbulence
Low reliability

Source definition

Results in close field
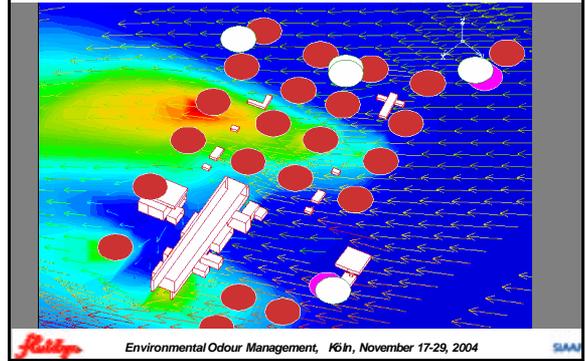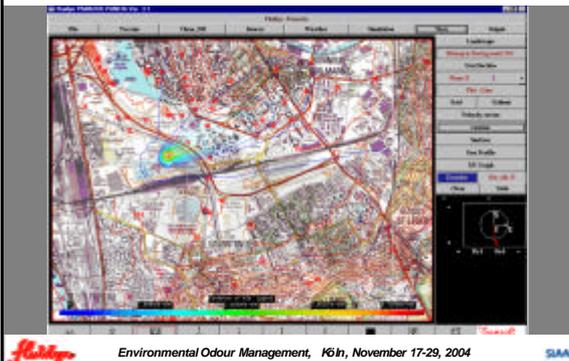
Results

II. Source identification

Methodology

- Alert from a monitor point set at a given threshold concentration
- Software backtracks in time
- Retrieves the corresponding wind fields from database
- Dispersion with puff model from all sources
- Integration of concentration per monitor point
- Identification of the source at the origin of the alert with a probability factor
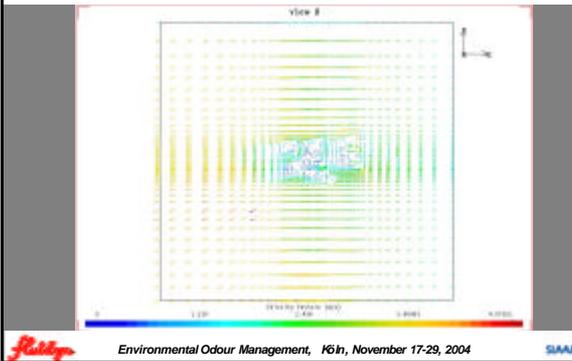- Refining of results with Eulerian model and further information
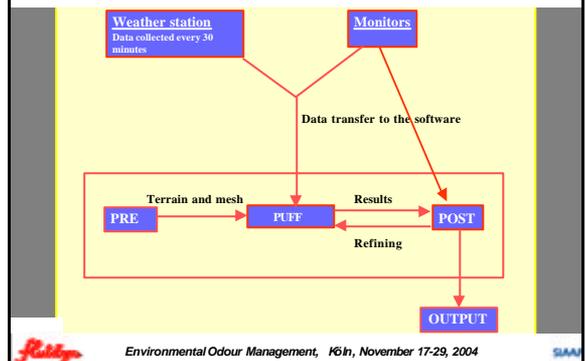
Set-up

Results

Results

H$_2$S Iso-concentrations
with temporal wind variations
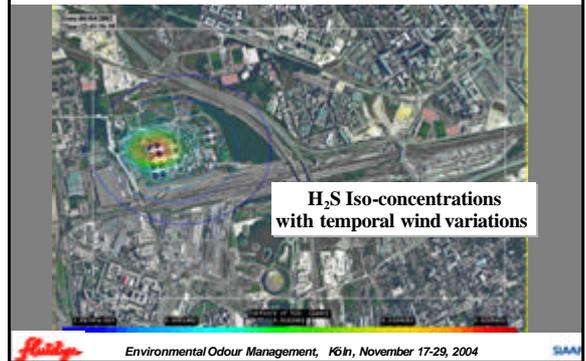
Results
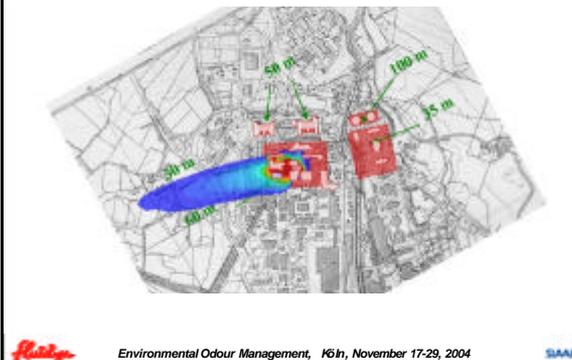
Thank you for your attention